Guidelines for Land Treatment of Industrial Waste

Alberta
ENVIRONMENT

GUIDELINES FOR LAND TREATMENT OF INDUSTRIAL WASTES

Prepared by:

ENVIRONMENTAL PROTECTION SERVICES
ALBERTA ENVIRONMENT
JUNE 1988

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1. INTRODUCTION

The use of the surficial soil to manage waste by relying on the action of soil microorganisms to degrade waste constituents has been referred to as land spreading, land application, sludge farming, landfarming, land disposal, soil cultivation and land treatment. Throughout this guideline the adopted designation will be land treatment, since it implies that an environmentally acceptable treatment of the waste will be achieved in an organized process characterized by planning and post-application care, both of which are vital to proper waste management.

Land treatment of industrial wastes is the process of controlled application of wastes on the soil surface and the incorporation of the waste into the upper soil zone in such a manner that by using the natural capacity of the soil system the waste constituents are physically, chemically, or biologically degraded, assimilated and immobilized within the treatment zone.

This guideline applies only to land treatment of industrial wastes. The use of agricultural lands for treatment and disposal of municipal waste water sludges is addressed in the document "Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands", published by Alberta Environment in 1982.

One time application to land of certain by-products or wastes mostly inorganic in nature such as lime, contaminated sulphur or drilling muds is not considered land treatment but rather soil conditioning or land disposal. However, this practice can also be effectively conducted by following with some adaptations the general principles that apply to land treatment of wastes.

In the last few years, management of biodegradable wastes by land treatment has increased in Europe and the United States. In Alberta the technique has been the object of on-going field and research work, and at the present time a few plots of land, mainly zoned industrial, are being used to treat industrial biosludges, refinery wastes, and oil field wastes at several sites approved by Alberta Environment.

The major advantages of land treatment as a waste treatment/disposal method are:

A. Effective at a comparatively reasonable cost;

B. Relatively safe when compared with alternative treatment/disposal methods;

C. Uses natural processes for treating the waste;

D. Relatively simple process; and

E. May improve soil structure and fertility.

The Department's objective in preparing this document is to establish minimum requirements for the design and operation of a land treatment facility (LTF) consistent with the principle of protecting human health and the environment.

Approvals for LTF are required from Alberta Environment under provisions of the Clean Water Act. This guideline outlines the primary criteria considered by the Department in reviewing applications. Appendix 1 provides a copy of an application form for a Permit to Construct and a Licence to Operate the facility.

The requirements described herein will be applied to LTF established after the issuance of the guidelines. For existing operations a licence to operate must be obtained from the Director of Standards and Approvals at the time of the renewal of the Clean Water Act Licence. Continued operation of existing facilities will be contingent on a site specific evaluation of observed impacts on the environment.

For additional information on land treatment of wastes, a number of selected references are given at the end of the text. They include most of the background material used in the development of these guidelines.

2. SITE RESTRICTIONS

Proper site selection of a LTF is needed to achieve treatment of the waste at the lowest operational and post-closure costs while protecting human health and the environment. The following site related factors should be carefully considered when locating a LTF.

2.1 Potential sites should avoid residential areas, forested and prime agricultural land, wetlands, permafrost areas, critical wildlife habitats, drainage ways, and areas subject to seasonal flooding.

2.2 The general topography of the area where a LTF is to be located shall be slightly graded to avoid water accumulation within the site. Slopes up to 9% are acceptable, but sites with slopes higher than 4% should be distant from water courses, receive reduced application rates of waste or be graded or terraced to provide good surface drainage and run-off control.

2.3 Ideal soil parameters for a LTF site are as indicated in Table I:

2.4 The treatment zone of a LTF shall be confined to the surficial unsaturated layer of soil. The maximum depth of the treatment zone must be at least 1 meter above the water table.

2.5 Minimum climatic conditions in the area where a LTF is to be developed should provide, on average, a frost free period of approximately 100 days and a desirable thermal period (temperatures greater than 10°C) longer than 60 days. Precipitation should also be taken into account.

Table I - Ideal Soil Parameters

Parameter	Specification	Dependent Variables
A. Soil type (unified system)	sandy loam, clayey loam	- too much sand encourages leaching; too much clay induces hardpan and ponding
B. Soil permeability	10^{-3}-10^{-6} cm/s	- moderate permeability prevents leaching and surface ponding/runoff
C. Cation exchange capacity (CEC)	>20 meq/100g	- high CEC will increase the retention of metals and minimize mobilization in groundwater.
D. pH	6.5-8.5	- low pH permits metals mobilization in groundwater; very high pH may also permit metals mobilization; both extremes deter microorganisms

Note: The specifications provided in this Table are "ideal" parameters, and actual operational parameters may be different from the above.

3. WASTES SUITABLE FOR LAND TREATMENT

Characteristics of suitable wastes are such that the ecological balance of the soil/plant/water system shall be maintained, if land treatment is conducted using good operational practices. Wastes to be land treated should be susceptible to biodegradation in the soil environment, create no offensive odours at site boundary and not pollute ground water.

For each waste that will be land treated, the applicant for a licence must reasonably demonstrate that the constituents in the waste can be sufficiently degraded, transformed and immobilized by physical, chemical or biological processes in the treatment zone. The demonstration can be made by using field tests, laboratory analyses, available data, or in the case of existing facilities, operating data.

Examples of acceptable wastes for land treatment are:

A. Oil field wastes (oily sands, pit cleanings, treater sediments, separator and tank bottoms, and oil spill debris).

B. Refinery wastes (oil-water separator sludges, desalting sludges, flotation froth, flocculation sludge, tank bottoms, biosludge, filter clays, settling pond sludges and oil spills debris).

C. Food processing wastes (from breweries, yeast-plants, snack food facilities).

D. Pharmaceutical (degradable waste streams).

E. Organic-chemical (non-biopersistent wastes).

F. Sludges from biological treatment of industrial wastes.

4. DESIGN AND OPERATION

Basic to the design and operation of a LTF is a good understanding of the local hydrogeology and a description of the chemical and physical characteristics of the candidate waste.

Considering that the treatment of the organic constituents of waste is the result of microbial action, factors that may affect that activity such as temperature, pH, solubility, moisture, and oxygen and nutrient requirements, should be assessed.

Important hydrogeologic considerations include depth to the water table, characteristics of surficial soil, groundwater flow direction and depth to the uppermost aquifer. Appendix 2 provides additional information on ground water evaluation and details for construction of observation wells.

The characteristics of the waste shall be investigated prior to application for a licence to operate in order to decide on the frequency and quantity of waste that may be applied, the amount of nutrients required, moisture control and frequency of cultivation. Composite samples are required to obtain representative analyses. Parameters may include but not be limited to:

A. pH;
B. water and solids content;
C. oil and grease;
D. total organic carbon;
E. plant available and total nutrients (N and P);
F. major water soluble ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, NO_3-, and $SO_4$2-); and
G. metals (Cd, Cr, Cu, Hg, Ni, Pb, and Zn).

Specific parameters may be required depending on the nature of the waste; for example, volatile components, phenols and polyaromatic hydrocarbons in oily sludges.

Not limiting the foregoing, the following should be taken into consideration at the design stage and during operation of the facility (a typical land treatment facility, that does not necessarily portray minimum requirements, is depicted in Figure 1).

4.1 Application rates of waste to the land treatment site shall be such as not to exceed the assimilative capacity of the soil system for the limiting waste constituent. For example, oily sludges shall be applied as not to exceed, in representative samples, an average of 5% by weight of oil in the top 15 cm of soil after cultivation.

4.2 Reflecting average Alberta's climatic conditions, wastes shall not be applied to a LTF from October 31 to the next April 15, during rainfall periods, or at other times when the soil is saturated with water, ice-covered, snow-covered, or frozen.

4.3 Appropriate facilities for storage of the waste in winter months and wet weather conditions should be included in the design of a LTF.

4.4 Soil amendments such as organic matter, lime or fertilizers shall be applied incrementally as necessary to keep the soil pH and CEC within the acceptable range and to ensure an adequate supply of nutrients to the microbial population. Allowance may be made for the nutrient content of the sludge and the soil.

4.5 Aerobic conditions to maximize microbial activity shall be maintained by cultivating the surficial soil every two to four weeks and for as long as the site is used for land treatment.

4.6 Surface water run-on shall be prevented from entering a LTF by providing adequate diversion structures around the site. The run-on control system shall be capable of preventing flow onto the treatment zone during peak discharge from a 24-hour, 10-year storm.

4.7 Surface water run-off from a LTF, before release to the surrounding watershed, should be such that the limits in Table II are not exceeded.

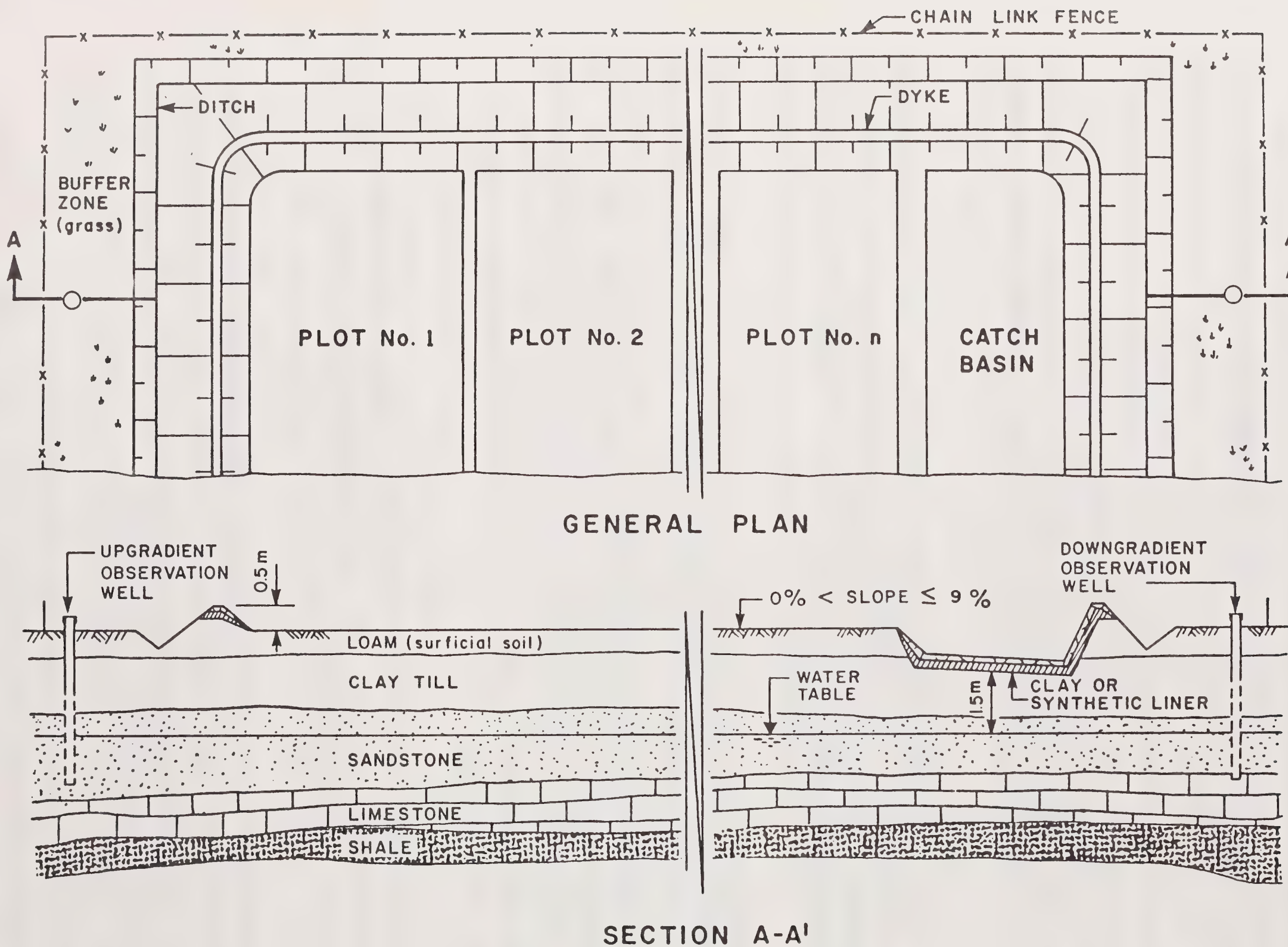

Figure 1. Typical Land Treatment Facility

The run-off management system shall be able to accommodate the water volume resulting from a 24-hour, 10-year storm.

Table II - Run-Off Allowable Limits

Parameter	Concentration or value
A. Chemical oxygen demand	50 mg/l
B. Oil and grease	10 mg/l
C. pH	6.5-8.5 units

4.7 A LTF shall be provided with a groundwater monitoring system consisting of observation wells located hydraulically upgradient and downgradient of the facility so as to yield samples representative of the background quality of the groundwater. The completion of the observation wells must be at an appropriate depth as to provide an indication of the potential impact on the upper water-bearing strata. Preferably, each sampling station should include observation wells at different depths in the groundwater zone.

4.8 The objective in designing and operating a LTF is that the ground water quality hydraulically downgradient of the facility remains the same as that upgradient, or it does not exceed the health related parameters of the Guidelines for Canadian Drinking Water Quality. In addition, background water quality parameters must not be exceeded in adjacent ground water supply wells.

4.9 The total quantity of waste applied to a LTF is limited to the amount which, by not exceeding the assimilative capacity of the soil system, will not jeopardize the planned future use of the land.

4.10 There is no specified limit on the size of a LTF; however, applications for large facilities will be subject to the same scrutiny as for small ones.

4.11 If the LTF handles waste that by its nature may be a source of particulates or odorous emissions at the boundary, the operator must incorporate in the facility design and operation adequate controls to mitigate potential problems. Pre-treatment, direct injection of the waste into the soil, immediate tillage after application, or buffer zones may be some of the procedures to minimize air impacts.

4.12 Access to a LTF shall be restricted to authorized personnel and controlled by the operator.

5. MONITORING AND REPORTING

Groundwater and soil monitoring systems must be included in the design of a LTF and data reflecting background conditions should be obtained prior to commencement of operation. Later on, monitoring programs will provide information to assess performance, to quantify impacts on the surrounding groundwater and soil, and to establish the acceptable frequency for waste application. Evidence of adverse impact, as shown by a statistical assessment of the monitoring data, will result in the implementation of remedial action. The following should be considered in developing a monitoring strategy for a LTF.

5.1 The background quality of groundwater and surface water in the potential zone of influence of a LTF is to be determined prior to commencement of operation of the facility, based on values obtained from at least quarterly sampling for one year period.

5.2 Before sampling, the water level in the observation wells shall be recorded and the wells purged of stagnant water stored inside the well casing and water in the formation immediately adjacent to the well to ensure that a representative sample of groundwater is obtained.

5.3 Samples shall be taken from the groundwater monitoring system at least twice a year for chemical analyses. Typically, the analyses required may include some or all of the following parameters:

A. pH (field and laboratory values);
B. major ions (calcium, magnesium, sodium, potassium, chloride, nitrate and sulphate);
C. chemical oxygen demand;
D. total organic carbon;
E. total dissolved solids;
F. oil and grease;
G. electrical conductivity;

H. heavy metals; and

I. specific tests in accordance with the type of waste being land treated.

Long term analytical requirements are dependent on previous monitoring results and subject to adjustments with the renewal of the licence to operate.

5.4 Analyses of all ground water samples shall be conducted either:

A. in the manner described in the publication "Standard Methods for the Examination of Water and Wastewater", 16th Edition (1985) or the most recent edition, published jointly by the American Public Health Association, American Water Works Association, and the Water Pollution Control Federation; or

B. in the manner described in the "Methods Manual for Chemical Analysis of Water and Wastes" (1987), published by Alberta Environment; or

C. by any other equivalent method which has been approved in writing by the Director of Standards and Approvals.

5.5 A minimum of 20 surficial soil samples (0-15 cm depth) shall be collected from each hectare of the land treatment site prior to operation and each September thereafter, during the active life of the facility. A grid pattern comprising 20 separate areas shall be set out in each hectare and the surficial samples taken from the geometric centre of each individual area. These samples shall be combined to form a composite sample that shall be tested for some or all of the parameters indicated in Table III. For trace metals, total and leachable concentrations are required. The leachate shall be prepared following the extraction procedure indicated in the licence to operate.

5.6 Core samples representing the soil profile to a depth of 90 cm shall be obtained by compositing sub-samples from four cores in each hectare of the treatment area. Sampling shall be done prior to the initial application of waste and each September thereafter, during the active life of the facility. The four sampling sites shall be at the same general location every year and regularly spaced within the hectare being sampled. The cores shall be divided into sections (depths 0-15 cm, 15-30 cm, 30-60 cm and 60-90 cm) and material representing the same depth in each of the four cores shall be mixed thoroughly to provide a representative composite sample which is to be analyzed for some or all of the parameters indicated in Table III.

5.7 Upon collection of the core soil samples referred to in subsection 5.5, the bore holes shall be adequately sealed to minimize potential pathways for contaminant migration.

5.8 Soil sample analysis shall be conducted in a manner described in the following references:

A. McKeague, J.A. (ed), 1978, "Manual on Soil Sampling and Methods of Analysis", 2nd Edition, Canadian Society of Soil Science; and McGill, W.B. and M.J. Rowell, 1980, "Determination of Oil Content of Oil Contaminated Soil", The Science of the Total Environment, 14:245-253; or

B. an equivalent method which has been approved by the Director of Standards and Approvals.

5.9 The owner/operator of a LTF will be required by his licence to operate to forward to the Director of Pollution Control, at the end of each year, a report which shall include:

A. location, quantities, and physical and chemical description of the waste applied to the LTF;

B. the ground water and soil monitoring data pursuant to this section; and

C. a statistical assessment of the monitoring data to show any statistically significant change of background values. (Examples of acceptable statistical procedures to detect contamination in ground water are described in the Federal Register, Vol. 52, No. 163, August 24, 1987 "EPA Statistical Methods for Evaluating Ground Water Monitoring from Hazardous Waste Facilities; Proposed Rule".)

Table III - Soil Analyses

	Parameters	Surface	Subsurface
A.	textural class	x	x
B.	pH	x	x
C.	oil and grease	x	x
D.	moisture intake and retention	x	-
E.	major ions (Ca^{2+}, Mg^{2+}, NH_4+, Na^+, K^+, Cl^-, NO_3-, and SO_42-)	x	-
F.	plant available NH_4-N+NO_3-N	x	-
G.	plant available P	x	-
H.	total organic carbon	x	x
I.	metals (Cd, Cr, Cu, Hg, Ni, Pb, and Zn)	x	x
J.	electrical conductivity	x	-
K.	cation exchange capacity (CEC)	x	x
L.	sodium adsorption ratio (SAR)	x	-

Note: Other specific tests may be required depending on the type of waste being applied to land.

6. CLOSURE

Closure of a LTF occurs when there is no further treatment of waste on site as opposed to the last application of waste. At this stage, the site shall be the subject of a decommissioning program.

The objectivies of this program are to:

A. make the site safe for the next use; and

B. to ensure that contaminants which may be on the site will not adversely affect the environment beyond the site boundaries.

REFERENCES

Alberta Environment, EPS, 1987. "Guidelines for Industrial Landfills".

Beak Consultants Limited, 1981. "Landspreading of Sludges at Canadian Petroleum Facilities". Petroleum Association for the Conservation of the Canadian Environment, Report No. 81-SA.

Environmental Protection Agency, 1987. "EPA Regulations for Owners and Operators of Permitted Hazardous Waste Facilities". 40 CFR 264, Environment Reporter. Published by the Bureau of National Affairs, Inc., Washington, D.C. 20037.

Environmental Research & Technology, Inc., 1983. "Land Treatment Practices in the Petroleum Industry". American Petroleum Institute.

Overcash, M.R. and D. Pal, 1979. "Design of Land Treatment Systems for Industrial Wastes: Theory and Practice". Ann Arbor Science, Ann Arbor, Michigan.

Peake, E., D. Connery, D. Holowachuk and W. Weibe, 1985. "Land Treatment for the Disposal of Oil Waste Sludges". The Canadian Petroleum Association and Alberta Environment Research Trust.

Todd, D.K., 1959. "Ground Water Hydrogeology". John Wiley & Sons, Inc., New York.

APPENDIX 1

APPLICATION FORM FOR APPROVAL

OF A LAND TREATMENT FACILITY

THE CLEAN WATER ACT

Application for A Permit or Licence

TO: ALL APPLICANTS FOR LAND TREATMENT FACILITY APPROVAL

1. All sections to be completed by applicant.

2. The completed application and attachments are to be sent to:

Director of Standards and Approvals
Standards and Approvals Division
Alberta Environment
4th Floor, Oxbridge Place
9820 - 106 Street
EDMONTON, ALBERTA
T5K 2J6

THE CLEAN WATER ACT

APPLICATION FOR APPROVAL OF A LAND TREATMENT FACILITY

Application No.: ______________

Date Received: ______________

Review By: ______________

For Office Use Only

Section One: General Information

1.1 Date of Application: ______________

1.2 Name, address and phone number of applicant: ______________

____

1.3 Name, address and phone number of owner/operator: ______________

____

1.4 Legal land description of the treatment site: ______________

____

1.5 Current land use and zoning: ______________

____

1.6 Applications for:

A. A permit to construct ______________

B. A licence to operate ______________

1.7 Summary of project: ______________

____

____

____

1.8 Duration of project: ______________

____

Section Two: Geographical Features

Scale diagrams of the land treatment site and surrounding area are required. These diagrams shall include:

2.1 Topography of the area;

2.2 Site boundaries and land use of the area; and

2.3 Location of all water bodies and water supply wells within a 500 m radius of the site.

Section Three: Soil Characteristics

The description of the soil shall include:

3.1 Soil description including geological parent materials, internal drainage characteristics, and type and depth of genetic horizons;

3.2 Physical characteristics including water saturation percentage, texture, hydraulic conductivity, and moisture intake and retention; and

3.3 Chemical characteristics including pH, major ions, metals, electrical conductivity, cation exchange capacity and sodium adsorption ratio.

Section Four: Hydrogeological Characteristics

The description of local hydrogeology shall include the following information:

4.1 Water table level;

4.2 Shallow groundwater flow direction and rates;

4.3 Background quality of groundwater in the upper water-bearing strata within the expected zone of influence; and

Section Four: Hydrogeological Characteristics (cont'd)

4.4 Present and future groundwater uses which could be affected.

Section Five: Design and Operation

Details on design features and operational procedures shall include:

5.1 Chemical analysis and physical characteristics of the sludge to be land treated;

5.2 Quantities, application methods, rates and cultivation frequency;

5.3 Soil amendments (pH control, organic matter and nutrients);

5.4 Surface run-on and run-off control systems; and

5.5 Physical features (slope, dykes, buffer zones and perimeter fences);

5.6 Associated sludge storage facilities.

Section Six: Monitoring System

A full description of the groundwater and soil monitoring systems within and around the land treatment site shall include:

6.1 Proposed number and location of groundwater observation wells;

6.2 Details on the completion of observation wells (depth, screening interval, construction material, casing and annular seals).

6.3 Proposed surface and subsurface soil monitoring system.

Section Seven: Closure and Reclamation

A discussion regarding closure procedures, reclamation plan and the end use of the land shall be provided.

Section Eight: Local Authority Approval

Provide copy of development permit.

Section Nine:

This application is submitted in accordance with the Clean Water Act and may require the applicant to submit any additional information considered necessary regarding the proposed land treatment facility.

An application for a Permit or Licence shall not be deemed to be filed until all the information, documents and authorizations in the application form have been received.

____

(Date)

____

(Signature)

____

(Title of Signature)

NOTE: The application must be signed by the owner or his agent.

APPENDIX 2

GROUNDWATER EVALUATION

AND DETAILS FOR CONSTRUCTION OF OBSERVATION WELLS

1 INTRODUCTION

The potential impact on groundwater resources is one of a number of factors which require consideration during the site selection and operation phases of land treatment facilities. To achieve this objective, an investigation standard must be established to obtain the necessary hydrogeologic data to properly evaluate each site. The following is a generalized outline of the data necessary for this evaluation. Since each site represents an unique hydrogeologic environment, the number and position of testholes and observation wells is dependent on existing site conditions. Therefore, only general guidelines can be established and investigations must be designed on a site-specific basis.

Prior to embarking on a field program, the general hydrogeology of the site must be investigated by a review of available data. This review should establish the regional hydrogeologic setting within a three kilometer radius of the proposed site by presentation of lithologic information, identification of water well locations and aquifer yields. The actual placement of instrumentation will be dependent on the site geology determined during the drilling phase. To ensure an adequate number of wells, the proper positioning of wells and accurate site evaluation, the investigation should be supervised or conducted by personnel experienced in groundwater investigations (preferably a hydrogeologist).

2 GROUNDWATER OBSERVATION WELLS

2.1 Piezometers

Observation wells are classified as either piezometers or water table wells depending on construction. Piezometers are used to:

A. isolate a specific zone to enable sampling of groundwater;

B. measure the hydraulic potential at specific points below the water table. Short sections of screen (0.5 to 1.0 m) are placed opposite the zone to be monitored and all zones above and below the screen are sealed off. Groups of piezometers, or nests, are often used to determine the hydraulic potential at different depths, thus enabling the determination of the vertical component of groundwater flow (recharge, discharge or lateral flow conditions). A piezometer in combination with a water table well can also be used provided the water table is not perched; and

C. determine the hydraulic conductivity of the geologic materials in which the piezometer has been completed by conducting a dynamic response test or "slug test".

2.2 Water Table Wells

The upper surface of the zone of saturation is called the water table. It can further be defined as the surface of atmospheric pressure and would be revealed by the level at which water stands in a well. The shape of the water table is controlled partly by the topography of the land and generally tends to follow the slope of the land surface.

Water table wells are observation wells which contain long sections of slotted pipe allowing the entry of groundwater along most of the well depth. Water table wells are used primarily to determine the water table depth and the lateral direction of groundwater flow. The slotted section of water table wells should extend above the anticipated water table depth but should not extend large distances below the water table. Should the well screen or slotted interval extend to a confined permeable zone below the water table, the water level in the observation well may reflect the hydraulic potential of the more permeable zone.

Due to annual fluctuations in the water table level, the specific results of a water table observation well network should be evaluated with respect to other attributes of the site gathered by site inspection and examination of aerial photographs. A number of factors such as weather, surficial stratigraphy, topography and flooding affect the water table level. Vegetation type and soil development tend to reflect the interplay of these factors and the resultant long-term range of water table levels.

2.3 Stabilization of Water Levels

It is essential that observation well water levels have stabilized prior to using the data for preparing water table contour maps, assessing the vertical component of groundwater flow and the calculation of groundwater velocities. The stabilization period is dependent primarily upon the permeability of geologic materials. For example, wells completed in sand and gravel may stabilize within minutes while wells completed in clays can take several months to stabilize. Stabilization can be determined by assessing the relative change in water level between successive water level measurements conducted over a period of time. Minimal changes between readings or changes in the trend of the responding water level suggest stabilization has occurred.

2.4 Density of Observation Wells and Depth of Investigation

As previously stated, the density and positioning of observation wells is dependent on the hydrogeology of the site. The following can be used as a general guide:

A. It is recommended that observation wells be completed on a 200 m grid spacing. Generally a water table well would be completed at each drill site to define the water table.

B. The surficial and bedrock materials throughout the site should be identified in detail to a depth of at least 6 m below ground surface.

3 SITE MAPPING

Using the above criteria the following site maps should be prepared:

- site topography map; and
- water table contour map.

The maps should show the location and elevation of all observation wells (the wells must be surveyed) and other details of significance to site development. If bedrock is intersected during the investigation, a fourth map, bedrock topography should be prepared. One or more representative hydrogeologic cross sections through the site are also required.

4 DETERMINING GROUNDWATER VELOCITY

Single well response tests (slug tests) should be conducted in all piezometers in order to obtain representative in-situ hydraulic conductivities for various geologic materials within the depth of investigation. A textural analysis (sieve or hydrometer) of surficial materials taken at various intervals would supplement hydraulic conductivity determinations. As previously stated, a piezometer nest should be installed in at least one location to record the hydraulic potential at different depths, thus enabling the vertical component of groundwater flow to be determined.

Groundwater flow velocity (linear pore water velocity based on Darcy's law) is a function of hydraulic conductivity, hydraulic gradient and porosity of the porous medium, and is calculated as follows:

$$Vw = \frac{K \frac{dh}{dl}}{\theta}$$

where Vw = average velocity of groundwater through pores;

K = hydraulic conductivity (from slug tests conducted on piezometers);

$\frac{dh}{dl}$ = mean hydraulic gradient (slope of the water table);

θ = soil porosity (based on type of material).

5 CONSTRUCTION OF OBSERVATION AND MONITORING WELLS

5.1 Well Construction Materials

Plastic PVC or stainless steel pipe is recommended for the construction of water table wells and piezometers, with the final choice of pipe and screen material dictated by the waste being land treated. Casing with an inside diameter of 3.8 cm to 5.0 cm is most often used for completing observation and monitoring wells (see Figures I and II for construction details).

5.2 Piezometer Screens

A wide variety of piezometer screens (metal and plastic) are available commercially. The full length of screen must be backfilled with sand of suitable grain size. The sand should be coarse enough so that it does not enter the screen but fine enough to result in some filtration.

5.3 Water Table Well Screens

Water table wells are screened or slotted along much of their length as indicated previously. In order to reduce costs, water table wells may be constructed by slotting the well casing with a hacksaw. The annular space around the perforated section is then backfilled with either coarse sand or pea gravel.

5.4 Annular Seals

The annular space between the casing and the testhole must be sealed immediately above the piezometer screen to prevent hydraulic communication between different zones and also to prevent contamination by surface water. Bentonite clay (montmorillonite) is probably the most effective material since it swells when wet to form an excellent seal. The sand pack surrounding the piezometer screen should be extended 15 to 20 cm above the screen to limit the entry of bentonite into the screened zone. A 15 to 20 cm layer of bentonite pellets is then placed on top of the sand pack and the remaining annular space filled with cuttings. A bentonite seal should be placed at the surface for both piezometers and water table wells to prevent contamination by surface water.

5.5 Well Development

Prior to sampling, wells should be developed by bailing, flushing or pumping. The internal casing pressure must be minimized to avoid damaging the annular seal. Monitoring wells should be protected with locking caps and marked to prevent damage.

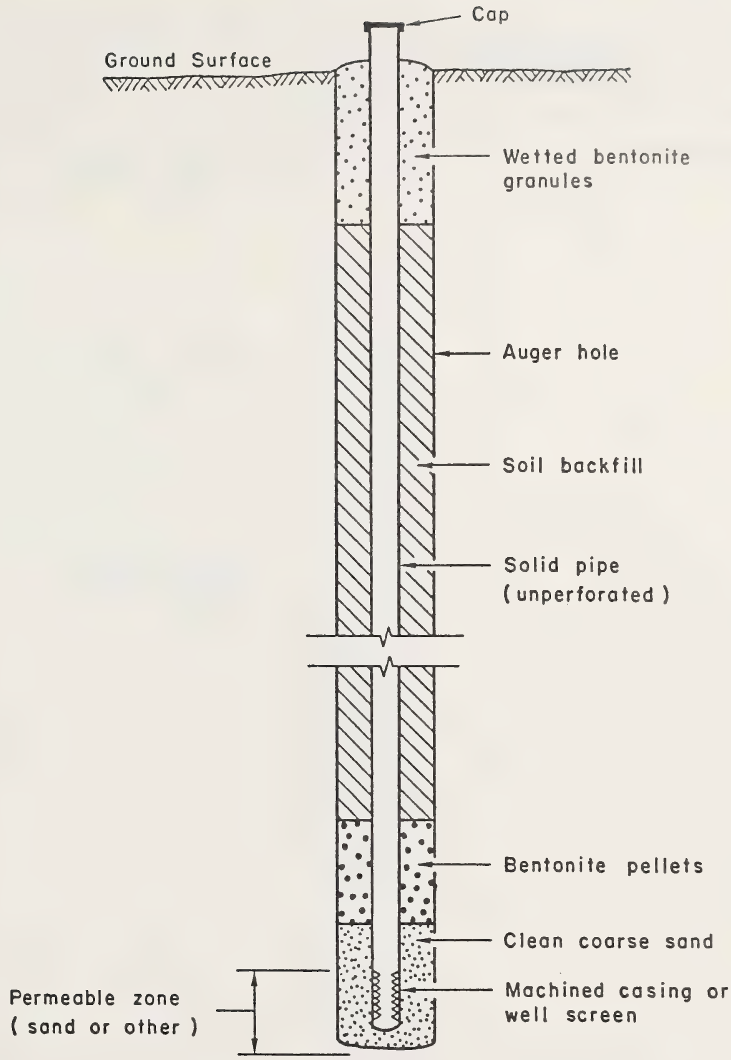

Figure I. Piezometer construction details

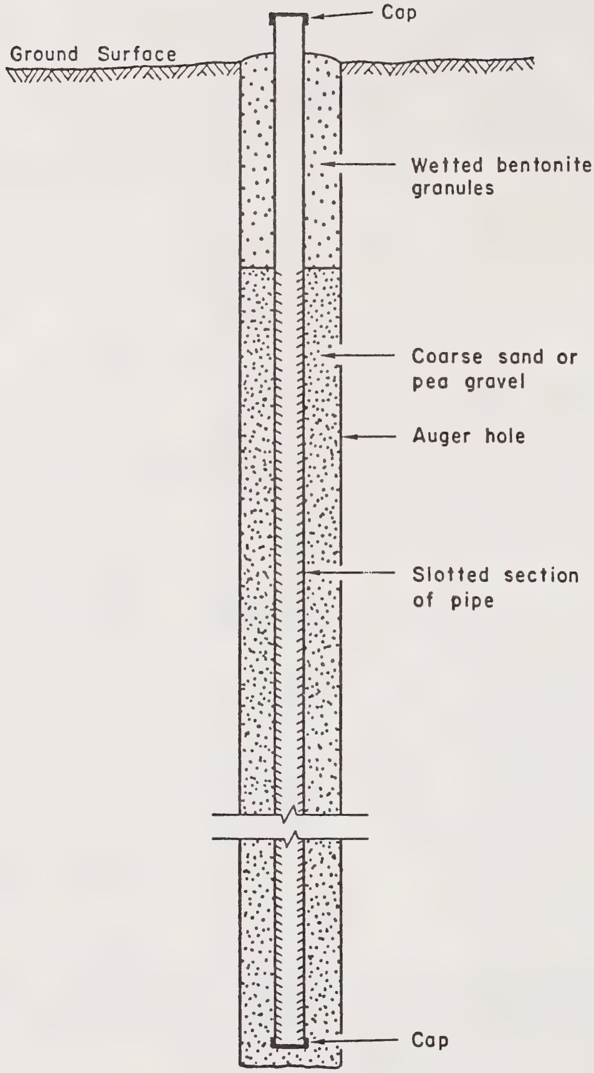

Figure II. Water table well construction details

6 BACKGROUND QUALITY OF GROUNDWATER

Should the site be approved, groundwater samples will be required to assess background water quality prior to LTF development. The requirement for groundwater monitoring should be considered during completion of observation wells so that the wells could later be incorporated into a groundwater monitoring system.